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RDS-ALERT:

A proposed Traffic Message Channel (TMC) feature for the Radio Data System (RDS)

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Summary

RDS-TMC is a proposed new RDS feature for FM Radio (VHF) which provides a means for conveying travel information in a densely coded digital form, along with a conventional VHF-FM programme signal, such that it is ***independent*** *of the normal sound programme. Using TMC, special RDS receivers employ decoding circuitry and digital storage to retrieve the messages and store them for future interrogation by a listener. Messages can be delivered in various ways — for example, a voice synthesiser could be used, in the language of the listener's choice.*

RDS-ALERT was one of about seventy projects within the European Community's research programme, DRIVE, and was concerned with the development of RDS-TMC. Work, carried out in the period 1989-90, had a primary aim to build a consensus amongst broadcasters, traffic authorities and receiver manufacturers in order to establish a future standard.*

The BBC participated in RDS-ALERT to ensure that TMC would serve the needs of public service broadcasting in the future and to provide advice for the most efficient use of the limited RDS data capacity. Field trials were made in the Wrotham service area in early 1990 to establish the system performance, using two early versions of an ALERT coding strategy (A & B). Evidence was gathered on message reception reliability and system performance using a novel approach. Error statistics of RDS reception in a mobile receiver over a wide range of routes and RDS transmission characteristics were collected. Subsequently these were used in the laboratory to simulate the whole transmission chain and allow different coding proposals for TMC to be tested and analysed under identical conditions.

It appears that, with an RDS deviation of ±2 kHz, an RDS-TMC Service might be provided using a data rate of just one RDS Group a second which is less than 10% of the total RDS capacity. This could be accommodated in existing BBC transmissions without prejudice to the integrity of the existing RDS Service. To achieve this, TMC messages must be kept short to ensure adequate reception reliability and the number of messages broadcast must be limited, probably to a few hundred at a time. With lower RDS deviations and/or where ARI signals are simultaneously present, RDS reception reliability may be only marginally adequate to support a TMC service.

A draft new coding proposal, ALERT C, has been developed as part of the work of RDS-ALERT and is based on the best aspects of the earlier A and B proposals. Although not yet formally adopted, ALERT C is suggested by the EBU and ECMT as a basis for future work. Further full-scale field tests of ALERT C are needed before deciding whether RDS-TMC would provide a useful traffic information service. These tests should also help to clarify the other, non-technical, features associated with such a service: for example, the cost and acceptability of receivers, integration of the information with that provided by other broadcast travel services.

* Dedicated Road Infrastructure for Vehicle safety in Europe

Index terms: *Radio broadcasting; data transmission; measurement; traffic*

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1. INTRODUCTION

1.1 Travel information

We have all suffered the frustration of traffic congestion, whether because of long-term roadworks or unpredictable accidents. Roadworks can be predicted and therefore avoided, but other problems can cause uncertain delays. It has long been recognised that there is a need for up-to-date and detailed information about traffic problems, and for ways of minimising the disturbance.

The traditional method of broadcasting traffic information to radio listeners has been to include reports in the scheduled programme output of both national and local radio. Finding this information can be difficult, generally requiring the listener to become familiar with which stations carry it and when. It can also cause annoyance to listeners who are not interested in traffic information. The first generation of FM radios which incorporate RDS (Radio Data System)[1,2,3] have gone some way to tackling this problem and, by means of the RDS Traffic Programme (TP) flag, a station can be identified as one which carries traffic information. When a traffic announcement is being made, an RDS Traffic Announcement (TA) flag allows a receiver to be unmuted or switched from a cassette mode to receive the messages. This is very similar to an older traffic information system called ARI* which is used extensively in the German-speaking countries of central Europe.

Second generation RDS radios are expected to go one stage further and allow a listener greater freedom in the choice of the station he wishes to listen to, whilst remaining primed to receive traffic information from another station. This is possible using the Enhanced Other Network (EON) feature of RDS which was pioneered by the BBC and is now broadcast throughout the UK on four national networks and about 40 local stations[4]. EON provides cross-reference to other networks carrying traffic information. If the listener wishes, the TA flags of the other networks can be detected so that the receiver can re-tune to their appropriate frequency for the duration of the message. A BBC-designed EON receiver, incorporating this 'vectored EON Travel feature' was demonstrated at IBC 90[4]†.

Although the vectored EON service is a major step forward, a further improvement in broadcasting traffic information could be provided using a proposed new Traffic Message Channel (TMC). TMC may be incorporated within RDS as a new feature and this development is the subject of this Report.

1.2 TMC

TMC provides an independent channel for traffic information using densely-coded digital data. A special TMC receiver would allow those listeners, interested in traffic news, to access it on demand and for a particular area or route of their choice. Their listening in the meantime need not be confined to the station carrying the traffic information. There would be a freedom to listen to radio programmes on other stations, cassette or CD. The digital nature of the stored information in the receiver permits it to be made available in different ways, such as via a voice synthesiser or in a visual or printed form. A further advantage of a voice synthesiser is that the message could be presented to a listener in his own language regardless of the country of origin of the broadcast.

Apart from avoiding the inclusion of traffic information along with mainstream programme material, the broadcaster enjoys two other advantages with TMC. He is able to target his audience and issue the information as it becomes available rather than waiting for a convenient time-slot in the programme schedule. A possible danger with such a system is overloading the driver with more information than he can cope with; this requires careful design to provide appropriate selection in the receiver.

A previous proposal for an independent traffic information channel called CARFAX[5] was developed by the BBC. This was an AM service, before the invention of RDS, but there were difficulties in allocating a suitable frequency to implement it. Furthermore, CARFAX would have needed a relatively expensive infrastructure of dedicated transmitters.

1.3 DRIVE

DRIVE‡ is a CEC (Commission of European Communities) funded major research programme concerned with improving vehicle safety in Europe. One of the seventy or so projects, carried out between January 1989 and December 1990, was called RDS-ALERT (V1029); its purpose was to take up the development of RDS-TMC and seek a broad consensus for its use. ALERT stands for Advice and Problem Location for European Road Traffic.

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* ARI stands for Autofährer Rundfunk Information.

† International Broadcasting Convention held at Brighton, UK, in September 1990.

‡ DRIVE stands for Dedicated Road Infrastructure for Vehicle safety in Europe.

RDS-ALERT was one of several projects in a category of information and broadcast systems and was one which has enjoyed a high profile and been highly regarded within the DRIVE programme. Related projects included SOCRATES (V1007), dealing with cellular radio transmission of traffic information, and PANDORA (V1010) which dealt with investigations into database handling, in connection with establishing digital maps for vehicle navigation. Other topics covered vehicle location via satellite, public transport, freight handling under different road conditions and weather information gathering.

The RDS-ALERT consortium was led by Castle Rock Consultants (CRC), a firm of traffic engineering consultants based in Nottingham and, apart from the BBC, the other partners were: the Centre Commun d'Etudes de Télécommunications et de Télédiffusion (CCETT), Philips, Bosch-Blaupunkt and the UK Transport and Road Research Laboratory (TRRL).

The specific objectives of BBC participation were to ensure that the facilities available from TMC would be compatible with the very limited RDS capacity available and that it would meet the needs of broadcasters and their listeners. The BBC's main rôle has been to conduct field trials of the proposed TMC coding systems. The results of these tests serve as supporting evidence which is essential to the process of building a consensus on the specification of the system: this evidence is also needed to persuade broadcasters, receiver manufacturers, motoring organisations and road traffic authorities to commit resources for developing RDS-TMC services and equipment.

This Report begins by describing how TMC works and how it can be fitted into the RDS structure. A brief background to the development of TMC is given prior to stating the test objectives. The test strategy is introduced in Section 6 and the criteria associated with the gathering of the field trial data follow. The bulk of the Report is devoted to examples of the test results using two earlier proposed coding strategies, referred to as ALERT A and ALERT B. In Section 10 the conclusions of these tests are discussed and an improved ALERT C coding strategy is introduced. ALERT C was developed in the RDS-ALERT project from the best features of the earlier proposals and the test results obtained are expected to support the new proposal.

An Appendix gives reference information about the ISO-OSI reference model used in the tests and further details of the test strategy and field trial data gathering exercise.

2. HOW TMC WORKS

2.1 TMC system

Basically, a TMC service requires four clearly identifiable actions in the communication chain. These are illustrated in Fig. 1 and may be described as:

- Collecting traffic information from remote sources.
- Editing and collating the information into messages.
- Encoding and emitting the messages.
- Providing suitable receivers.

The Police, road authorities, motoring organisations and other agencies such as tunnel and ferry authorities are already suitable sources of reliable and readily updatable traffic information. This information needs to be collected, collated and edited before being encoded into a format suitable for transmission (in this case shown as a broadcast). This process is governed by the limited capacity of the available data channel; hence messages need to be sorted so that, for example, the more urgent messages are given priority. Finally, receivers require a suitable data decoder and an adequate storage medium, as well as some form of message output facility, such as a voice synthesiser. Receivers must be simple to use and affordable.

Three communication link stages are associated with these actions. These are the links from the information gathering points to a Traffic Information Centre (TIC), the link from the editing and collation point to the emitter (broadcast transmitter shown here) and thirdly the transmission link to the listener which might be an over-air broadcast or some other medium such as a cellular telephone network like GSM[6]. The work of RDS-ALERT was primarily about the second action, namely the encoding of message data, and the third link stage as applied to broadcasting via RDS.

2.2 Message structure

The way in which messages are encoded on to an RDS carrier has to be chosen carefully if efficient use is to be made of the data capacity available. If speech was digitally sampled and the bit-rate reduced

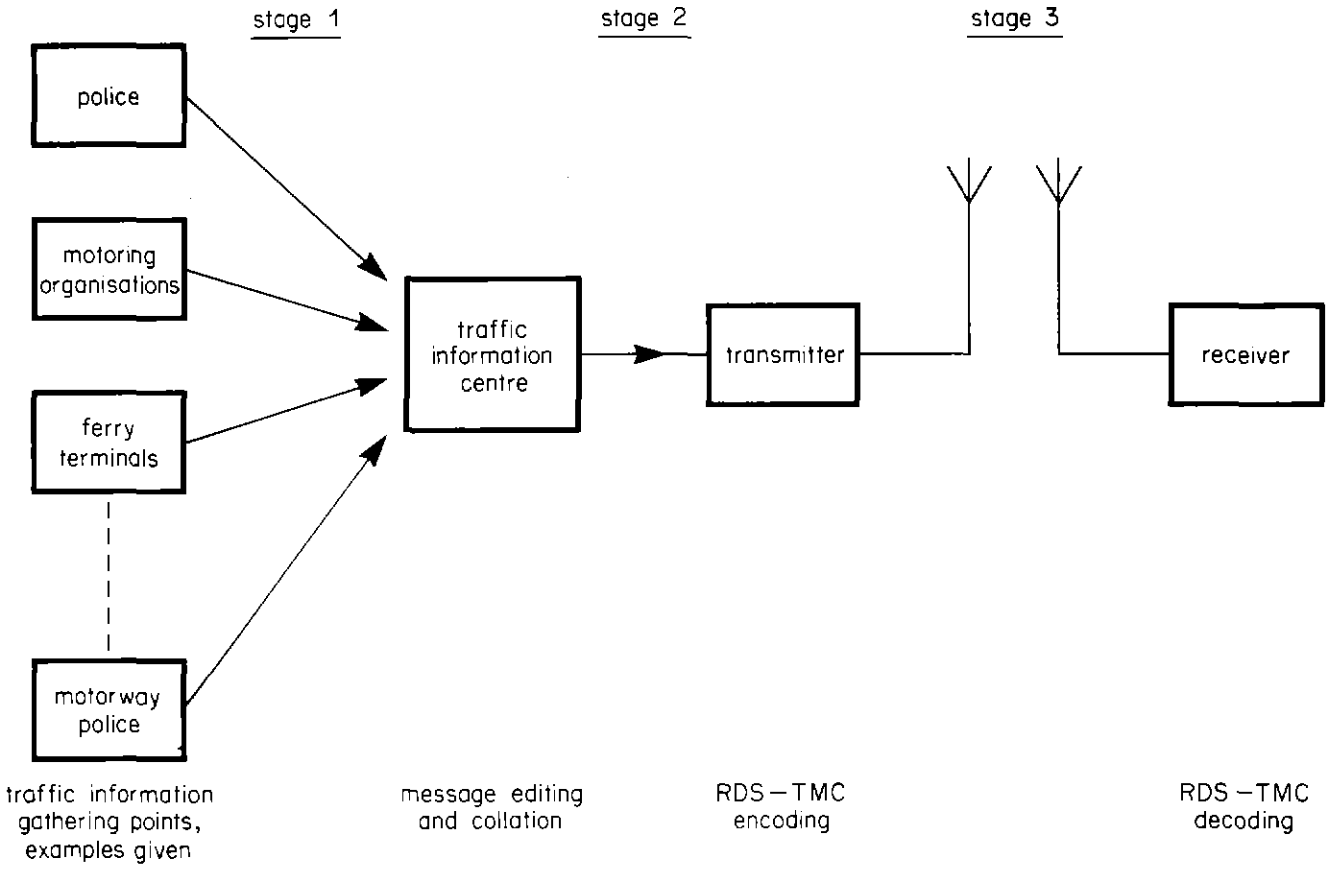


Fig. 1 - A TMC system with RDS broadcast carrier.

by any of the standard methods, the resulting data rate might still far exceed 16 kbit/sec. The only practical and efficient way to provide TMC was found to be in the form of a series of highly-compressed digital codes, which act as addresses to a fixed (and necessarily limited) repertoire of phrases contained within a receiver's memory. Complete messages can then be formed by a succession of such phrases. Earlier ideas for sending traffic messages via RDS were rejected. These included a text-to-speech conversion of the information sent, using the RDS Radiotext (RT) feature; and a phoneme transmission, using the RDS Transparent Data Channel (TDC) feature. Use of the very dense codes, now proposed, allows a system to occupy only, say, 40 bit/sec.

The proposed way in which the system works is based on reporting events as they happen and constructing messages to describe them. The message phrases used for an *event description* are drawn from a published list containing elements such as cause, effect, advice, duration, start time, etc. Not all elements appear in all messages and each message is made up as required. Only a relatively small set of phrases, with some room for future expansion, can be accommodated but this is expected to satisfy all foreseen requirements of participating countries.

Two other elements are associated with each message. These are a *location of the event* and *message management instructions*. Geographical locations need to be coded, again as a limited list, in such a way as to cover all parts of Europe at different levels of resolution. This includes major international motorway routes down to (in some cases) individual street corners as well as more generalised areas, such as the 'Black Forest'. Instructions for handling a message during the complete transmission chain apply to both the broadcaster and receiver. Message management instructions include servicing a regular flow of messages and, for example, distinguishing between background and urgent ones, introducing new messages and removing old ones.

An example of a typical TMC message, say number 20876, might be: 'A lorry has shed its load on the eastbound carriageway of the M25 between junctions 9 and 8; only the outer lane is in operation; delays are expected until midday'.

2.3 Message management

Messages are arranged in transmission cycles of up to a few minutes duration; these continually repeated cycles contain all *current* messages. This ensures that the delay time between message transmission and reception is kept to an acceptable level for receivers newly switched on or for motorists entering a new service area. Urgent messages are repeated more frequently in each cycle to make them available more quickly. New messages are inserted as they become available and obsolete messages are deleted. The cycle length determines the minimum delay which a receiver might expect for acquiring all messages after being switched on, or when changing service areas.

3. TMC AND RDS

RDS is the European standard data system for station identification and automatic re-tuning in FM radio broadcasting[1]. The data is carried at a low level on a sub-carrier added to the FM multiplex: this is effected in such a way that it does not interfere with the normal sound programme. The recommended RDS sub-carrier deviation is ±2 kHz out of the total of ±75 kHz FM deviation; although lower levels are used in Germany and also in the UK for BBC Radio 3. The RDS data stream of about 1200 bit/second is structured into *Groups* which are broadcast at a rate of about 11½ per second. A Group contains four *Blocks*, each containing 16 bits of usable data and additional bits for error protection and synchronisation. The reasons for this type of coding are discussed more fully in Section 5.2.

Different types of RDS Group are used for each feature of the system. The basic features provide station identification (PS) and automatic tuning. Other features include EON and Radiotext (RT). A new Group, Type 8A, has been allocated for TMC investigations. An indication of how a TMC message could be fitted in to a single Group is shown in Fig. 2. Some of the 64 bits available in each Group are used for addressing different Group types. They are also used for carrying data which needs to be repeated in all Groups, such as a Programme Identification (PI) code, which labels a programme service. There remain 37 bits in each Type 8A Group for TMC messages.

However, the rate at which Type 8A Groups can be broadcast is limited, because the basic RDS features take up more than three-quarters of the total capacity[7,8]. Fig. 3 shows the BBC use of the RDS data channel on BBC Radio 4 from the Wrotham transmitter in 1991. It appears that full use is made of the RDS channel already, but it is possible to reduce the repetition rate of some of the existing features to allow room for new ones. Even so, only about 10% of the total would be available by this means and this has to be considered the goal for TMC — about one Group per second. Broadcasters would, in general, need to choose carefully which RDS features to support, and then to balance their repetition rates in order to maintain the integrity of each application.

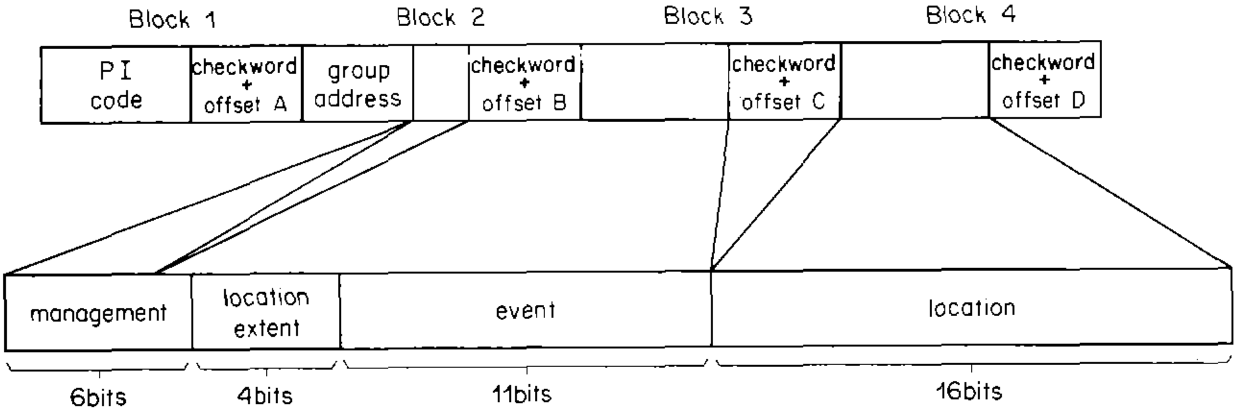


Fig. 2 - RDS Type 8A Group reserved for TMC.

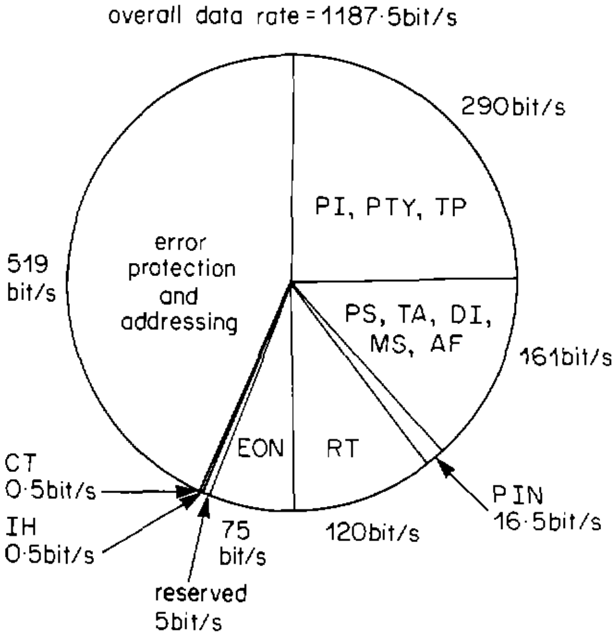


Fig. 3 - RDS capacity usage by the BBC from its Wrotham transmitter in 1991.

4. TMC DEVELOPMENT

4.1 Background

Several proposals have already been put forward to define a TMC using RDS. In 1987 the European Council of Ministers of Transport (ECMT) proposed a definition requiring two RDS Groups to contain each message. A modified form of this was adopted by CCETT and Philips for a Eureka sponsored CARMINAT project (EU55). Another proposal, by Bosch and the German road authority BAST, used just a single RDS Group. This approach was considered more rugged and occupied half the RDS data capacity — it could be used for more than 80% of messages envisaged. However, the flexibility of this proposal was questioned, and in 1987 the CEC invited Castle Rock Consultants to take TMC development a stage further. CRC produced a proposal for a modified single Group definition[9].

4.2 Standardisation

Although there were a number of independent field trials of these early proposals, there was no attempt at coordination until the RDS-ALERT project began in 1989. The standardisation of RDS-TMC is seen as an essential step, in order to permit TMC receivers to operate throughout Europe and to restrain receiver costs. A prerequisite to standardisation of RDS-TMC, is the approval of the European Broadcasting Union (EBU) and the ECMT.

5. TEST OBJECTIVES

The main objective of the tests, conducted by the BBC in the RDS-ALERT project, was to answer the question 'Will TMC work and provide a usable service within the constraints of RDS?'. Test results are required as supporting evidence in the consensus-building stages of TMC development and to facilitate the commitment of further resources. It was therefore necessary to establish to what extent TMC messages are corrupted by impairments from mobile reception of the FM signal; it was also necessary to determine how these can be minimised by an appropriate TMC transmission protocol/strategy.

The supplementary goals of these tests were:

i) to compare the performance of two particular coding strategies (ALERT A and B) which had emerged earlier in the project and which were the precursors of the currently proposed ALERT C protocol;

ii) to make recommendations regarding further technical improvements to either or both coding strategies.

The ALERT A proposal, although based on previous developments, had not been thoroughly tested. ALERT B, on the other hand, had grown up through the CARMINAT programme and many of the consequences of the coding strategy had already been explored.

A description is given next of a theoretical reference model on which the tests performed by the BBC were based. Following this, the reasons for requiring a field trial at this stage are substantiated.

5.1 ISO/OSI model

In the first year of the project, the BBC had worked closely with CCETT and CRC in defining the objectives and methodology for assessing RDS-TMC reception reliability. It was found to be convenient to base the assessment on the ISO-OSI seven-layered Reference Model for Open Systems Interconnection[10,11]. A fuller description of the model in this context is given in Appendix 1.

Essentially, this model treats the servicing of a particular application as a hierarchy of tasks, each of which contributes a different level of technical detail. In the case of an RDS-TMC application, the lowest layers of the model (Network and below) are defined by the existing RDS Specification[1]. These layers cover the addressable Group structure supported by a serial data stream modulated onto a carrier within an FM channel. These parameters have been referred to in Section 3.

The priority at this stage of TMC development was to test the middle layers of the ISO-OSI model which are Transport and Session. The function of the Transport layer is to incorporate the coded messages into the RDS Group structure, and to provide sufficient error protection for these messages. The protection required for a TMC application, where messages are relatively shortlived, is expected to be over and above that which is already provided within the existing RDS Specification for regularly repeated messages.

The Session layer is responsible for the management of the messages. This aspect has been introduced in Section 2.3 and includes the structuring of messages into repetitive transmission cycles; so that, for example, the more urgent ones are repeated more frequently, new messages are introduced and obsolete messages removed. In the receiver, this involves the storage and maintenance of a list of current messages and, for example, taking executive actions such as alerting a listener to urgent messages.

The highest Application and Presentation layers of the model were beyond the scope of this project. Their testing requires the availability of the other parts of a TMC system, as discussed in Section 2, namely a message input infrastructure and commercial receivers. This implies considerable future investment.

5.2 Why new tests?

The RDS-TMC feature is different from most other existing RDS features because the lists, of message data to broadcast, are continually changing: messages are broadcast for a period and then withdrawn. Although RDS reception reliability tests have been done in the past, they do not give sufficient insight into the way TMC message reception in particular might be affected. Moreover, there is no satisfactory model by which the effects of impairments in mobile reception of Band II broadcasts can be simulated in the laboratory. Therefore, the only practicable approach was to carry out a new field trial, to gather information about the error statistics associated with continually changing data. To understand more about the reasons for new tests, it is instructive to consider the nature of FM broadcasting, existing planning criteria, previous RDS developments and the tests and field trials which have already been conducted.

Mobile reception of Band II broadcast services is often impaired by multipath propagation which leads to distortion of the demodulated signals[8]. Multipath is caused by signal echoes from, for example, high-rise buildings and hilly terrain and its effect is best described as a characteristic audible 'crackling'. The quality of a received FM signal can vary enormously over short distances along a road, as the relative sizes and phases of the direct signal and echo signal components change. For a vehicle moving freely, the effects can be subjectively less annoying than for a vehicle stuck in traffic or held up at traffic lights. This is because the effects are relatively short-lived and good conditions can prevail for a large proportion of the time. VHF propagation is also sensitive to weather conditions, particularly atmospheric pressure gradients.

Multipath has a marked effect on the RDS received error-rate because of the relatively small size of the data signal component compared with distortion products[7,8]. The RDS insertion level, therefore, has a strong influence on the data reception performance. The level of distortion products is dependent on the amplitude and delay of the multipath components and the rate of movement of a receiver through a disturbed area. These factors are, in turn, dependent on the route topography and vehicle speed. Another contributory element to the level of distortion products, is the instantaneous audio programme modulation depth. This varies continually, and can cause differences in data reception between different programme services.

In the UK, FM radio broadcasting in Band II was originally planned for high-quality monophonic reception in the home using directional roof-mounted antennas. The planned networks were later developed to include stereophonic broadcasts, using the pilot tone system. The planning standard adopted in the UK for this purpose is based on a boundary limit at 54 dB (μV/m) contours as measured at an antenna height of 10 m above ground level[12]. A good service is, however, provided for motorists in main service areas. Car receivers are generally designed to revert to mono reception when the signal strength is low and this helps to overcome any localised weaknesses in the service coverage. RDS receivers have gone some way towards helping a motorist maintain good reception by automatically re-tuning to any neighbouring transmitters offering a better signal. This process occurs largely without the listener being aware of it happening.

From a technical point of view, RDS has been developed very carefully to optimise message reception reliability in a mobile reception environment. Laboratory measurements indicated that, with prototype receivers employing a Costas loop demodulator[13], the expected bit-error performance, following RDS demodulation for a given input signal level, could be within one decibel of that calculated from theory[7,8,13,14]. It was also recognised, that this error performance scales linearly if the RDS deviation level of the FM carrier is changed; i.e. the error rate increases for lower RDS insertion levels. Also, the theoretical performance of RDS, using a ±2 kHz deviation level, has been designed to remain satisfactory down to field strength limited conditions (random noise) at the receiver input. Such receiver input levels would render a monophonic audio signal noisy but still intelligible. [7,8,14].

The mean bit error rate, however, is not a true guide to RDS message reception performance. In practice, RDS reception errors occur in bursts and are not distributed randomly. Over a given stretch of road, for example, the mean error rate might appear reasonably low but the presence of short but high-level error bursts can adversely affect message reception.

Many field tests have been carried out in several countries of Europe, notably in the UK, Sweden and Germany, with the primary aim of optimising modulation and baseband coding aspects for mobile reception. More recent mobile tests were carried out in Germany[15] and the UK[16]. Both tests revealed statistics on the reception of single Block messages (such as PI) and interrelated Group messages (such as PS) and gave some indication of how other RDS features might behave. The former kind were more reliably received than the latter. This behaviour was also confirmed in BBC tests carried out in 1988 during the development of the EON feature[4]. The German tests, using a professional rebroadcast relay receiver, included compatibility aspects with ARI and it was as a result of these that the RDS deviation was recommended to be ±1.2 kHz when ARI is simultaneously present. The effect of reducing RDS deviation levels in general was also studied.

All of these tests have concentrated on the Physical and Data-link layers which lie below the Network layer of the standard reference model described in the last Section. The benefits of theoretical analysis and laboratory testing are strictly limited because realistic multipath conditions cannot be simulated satisfactorily. The only safe way to be sure that the interference is appropriate, is to gather the real error statistics on real roads, for a range of RDS transmission characteristics used across Europe. What was required was a more comprehensive series of tests to gather these statistics.

6. TEST STRATEGY

A novel method of testing a new RDS feature was developed, to overcome the problem of disturbing an existing RDS service or its associated equipment. In this method, the mobile measurement field trial on the road is separated from the testing of proposed RDS-TMC coding strategies, which is done later in a laboratory. The error statistics, associated with existing RDS transmissions, are not changed when new features are added. Once these are gathered, a new RDS feature can be tested using a simulated model based on these error statistics. The method relies on the large storage and signal processing capability of modern computer workstations to store the error files and to analyse the results.

A further advantage of this approach is that the results are repeatable because the same test conditions apply to all test data. This consistency allows independent observers to repeat the tests and obtain compatible results. This is important because of day-to-day variations which exist in VHF propagation. There can also be substantial savings on time and effort involved in repeating road tests. The development of this innovative testing method is of general application to digital communications systems.

The test strategy is described in more detail in Appendix 2.

7. GATHERING FIELD DATA

The key parameters involved with the gathering of data from the field trial may be summarised:

i) a variety of critical routes within the service area of a single high-powered transmitter. These routes should reflect a wide range of road conditions, include open country as well as urban environments and cover areas towards the boundary of the designated service area;

ii) a range of RDS deviation conditions including the presence of ARI;

iii) the use of commercial car receivers.

A specially equipped vehicle was used to carry suitable receiving and recording equipment around prescribed routes, in a test area located within the Wrotham transmitter service area. This area contains a substantial population in Greater London and the south-east of England. Existing RDS data broadcasts were used. This meant that the regular RDS service could continue, although some changes were made to the RDS modulation characteristics on BBC Radio 4 for very limited periods and under strictly controlled conditions. A 'clean' RDS data-stream was obtained at the same time as the mobile test runs by ensuring that an error-free signal was receivable at a good fixed location.

The test vehicle, chosen routes, RDS criteria and the acquisition of clean data during the field trial are all described in Appendix 3.

8. TRANSPORT LAYER TESTS

8.1 Objective

Testing at the Transport layer is concerned with ensuring that messages are not lost or received wrongly; the precise timing at which a message is received is not important. The key function is to check whether messages are received reliably. Important factors are: the number of correct messages received, the number of messages lost and the number of false messages. For each route type and RDS modulation condition, the results should give an overall picture of the interaction of the message length and the number of times a message is repeatedly transmitted.

8.2 Input parameters

The TMC message data at the Transport layer comprised a random bit pattern because the actual message content is not important. The data is carried in Type 8A RDS Groups as described earlier. Part of the 37-bit field available may be used for managing the conveyance of the data in the Group structure. This is a data management rôle at the Transport layer and falls outside the definition of a 'message'. The part of the field used for the actual message depends upon the coding strategy used, and was defined separately for ALERT A and ALERT B. For example, the ALERT B Protocol packs some messages into two sets of three bytes but with leading zeros in each set.

The TMC message data was combined with other background RDS Group types (Type 0A Groups with a zero field) to form a continuous input data stream. In all the tests, the TMC capacity was not allowed to exceed four out of eleven Groups.

Test message data was made available for the ALERT A coding by Bosch-Blaupunkt and ALERT B by Philips and CCETT. For reasons associated with the equipment provided by Blaupunkt, it was not possible to encode ALERT A multi-Group messages. ALERT B message data was provided for ½, 1, 2, 3, 8, 20 and 100 RDS Group-long messages. The respective message lengths for these are:

Number of RDS Type 8A Groups	½	1	2	3	8	20	100
Number of data bits	18	35	60	66	181	457	2297

In all cases the messages were repeated to give 2, 3, 4 and 5 transmissions of the same message.

8.3 Results

Because of the vast amount of data to process, a majority of these tests proceeded automatically overnight as batch jobs. This was made possible by incorporating a software-controlled receiver 'reset' mechanism in the serial connection between the workstation and the receiver under test (see Fig. A2.1). This ensured that the TMC receiver memory was clear of old messages prior to each test.

In all the tests performed, the receivers contained RDS demodulators which applied error correction on bursts of up to 5 bit errors. Also, each receiver adopted a strategy of accepting a message as being valid only after it had been received twice. With this strategy of additional error protection by repetition, no false messages were detected.

8.3.1 Reception reliability and efficiency

Fig. 4(a) shows a result of ALERT B coding in terms of the proportion of messages correctly received, compared with those transmitted, for a motorway route and with an RDS deviation of ±2 kHz. The proportion of messages received is given as a function of the message length and the number of times a message is transmitted. The reception efficiency decreases for longer messages but increases as messages are repeated. Longer messages are very unreliable. No false messages were received. The result, when averaged over all the routes explored, is given in Fig. 4(b).

The results for the three different route types tested and for an average over all routes, for two transmissions of a message, are summarised in Table 1. There is some spread in the results obtained for the different route types but this does not appear to follow any particular pattern. For short (single and half RDS-Group) messages, 80 to 86%, on average, are correctly received after just two transmissions.

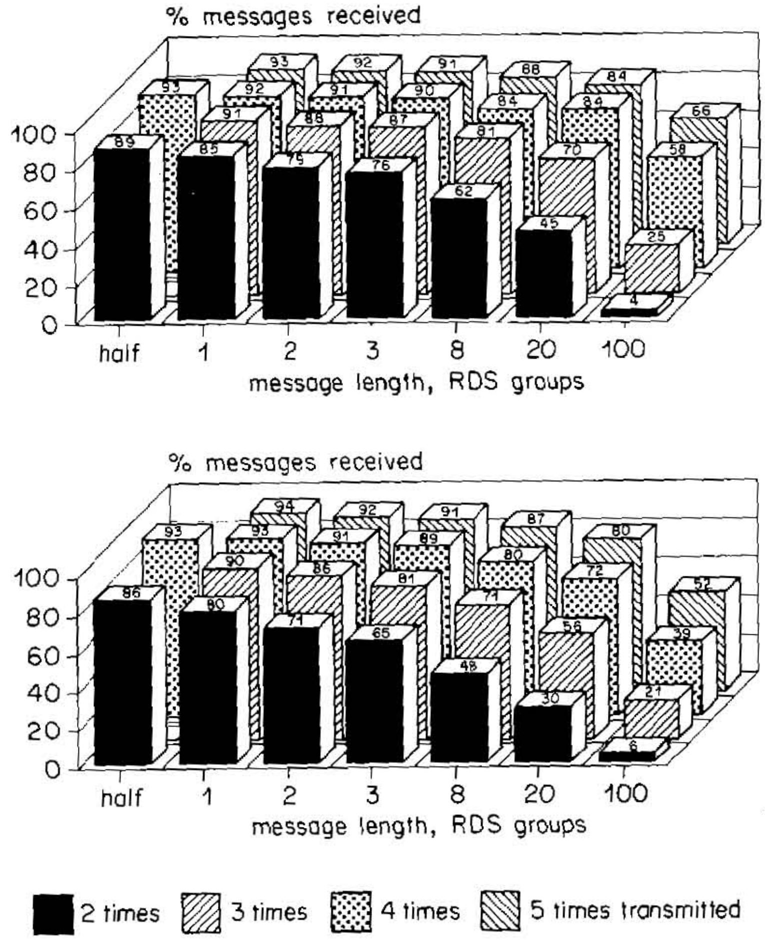
There is an overwhelming performance advantage when using short messages and the worsening of performance for any message exceeding a single RDS Group in length is noticeable. In particular, the large spread of message reception reliability for the longest messages, tested over different route types, is apparent.

Table 1

TMC message reception reliability using the ALERT B coding strategy and with ±2 kHz RDS deviation over different types of route and after two transmissions of a message.

Message length (RDS Groups)	Percentage messages received			
	Motorway	Urban	Mixed	All routes
½	89	91	78	86
1	85	87	70	80
2	79	80	54	71
3	76	75	44	65
20	45	35	10	30

Table 2 is a summary of the result of repeating message transmission for the average of 'all routes'. The 80 - 86% figure for shorter messages sent twice, rises to 93 - 94% after four or five transmissions. Longer messages require many transmissions to approach this level of efficiency. These further repeats of a message, however, only improve reception reliability at the expense of the total message throughput. This becomes an increasingly significant factor when a large number of messages are handled.



(a) Motorway route.

(b) All routes.

Fig. 4 - TMC message reception reliability using the ALERT B coding strategy and with ±2 kHz RDS deviation.

The total spread in message reception performance for the conditions used in Table 2 (ALERT B, ±2 kHz RDS deviation and for 'all routes') is summarised in Table 3. For a given message length, the spread is lower for shorter messages and after several message repeats. Longer messages can be received if repeated many times but this becomes increasingly wasteful of RDS capacity. In general, more than 90% of shorter messages are received under all road conditions, at the standard level of RDS deviation and after four transmissions.

As an example, and supposing that a TMC service might be based on just one RDS Group per second (about 10% of the total RDS capacity), 300 messages might be carried in a message cycle. If each

Table 2
TMC message reception reliability using the ALERT B coding strategy and with ±2 kHz RDS deviation over all route types and after multiple transmissions of a message.

Number of message transmissions	Percentage messages received				
	Message length (RDS Groups)				
	½	1	2	3	20
2	86	80	71	65	30
3		90	86	81	56
4	93	93	91	89	72
5		94	92	91	80

Table 3
TMC message reception reliability using the ALERT B coding strategy and with ±2 kHz RDS deviation after multiple transmissions of a message: minimum and maximum values measured over all route types.

Number of message transmissions	Percentage messages received, min-max				
	Message length (RDS Groups)				
	½	1	2	3	20
2	78-91	70-87	54-80	44-76	10-45
3		85-94	78-92	71-87	30-70
4	91-96	90-95	86-94	83-94	48-84
5		93-96	90-95	87-95	65-92

message is repeated within the cycle, the cycle would last for ten minutes. On the basis of the results given above, 70 -87% messages would be received after 10 minutes, 90 - 95% after 20 minutes and more than 95% after half an hour.

8.3.2 Data transmission efficiency

Although shorter messages are more reliably received, they carry less data and it is interesting to consider the trade-off between receiving many short messages and far fewer long ones. Repeating shorter messages reduces the net efficiency because the channel capacity is effectively eroded. Longer messages have to be repeated in order to achieve any respectable reception reliability. Table 4 expresses the results of Table 1 (ALERT B coding, standard RDS deviation) in terms of a 'transmission efficiency', where the key factor is the number of 'bits' which are conveyed correctly. Note, that the maximum value is just under 50% because the messages have to be received twice to validate them and some bits are used for the Transport layer housekeeping. Even on this basis, shorter messages are clearly more efficient.

Table 4
TMC message transmission efficiency using the ALERT B coding strategy and with ±2 kHz RDS deviation over different types of route and after two transmissions of a message.

Message length (RDS Groups)	Percentage usable data bits received			
	Motorway	Urban	Mixed	All routes
½	43	44	38	42
1	40	41	33	38
2	32	32	22	29
3	22	22	13	19
20	14	11	3	9

The effect on the average transmission efficiency, when messages are repeated, is summarised in Table 5 for 'all routes' and normal RDS deviation. The overall spreads for the same conditions are given in Table 6. For longer messages, there appears to be an optimum number of message repeats — notice the point of inflection in the response after three transmissions, which is evident in Table 5 for messages requiring twenty RDS Groups.

Two trends are evident: there is a greater spread for longer messages, and the spread reduces for multiple transmissions. The transmission efficiency appears to settle down to a more consistent value after four or five transmissions. For example, single Group messages sent five times return 18% over all routes.

8.3.3 Reduced RDS deviation and ARI

To illustrate the effects of reduced deviation, the results of message reception reliability are summarised in Table 7 and the extreme values given in Table 8. The lower deviation reduces reliability but this is more acute when ARI signals are also present. These results appear similar to those obtained in previous German tests[15]. The figures given here are actually distorted in the ARI case because a professional RDS decoder had to be used. The Costas loop demodulator, employed in the professional decoder, gives a better result than with other RDS demodulators. The first-generation RDS sets used simplified non-linear demodulators. If the tests at normal and reduced deviation were repeated with the same professional decoder, their results would also reflect an improved performance, so that the margin over the ARI results presented here would be significantly greater.

Table 5
TMC message transmission efficiency using the ALERT B coding strategy and with ±2 kHz RDS deviation over all route types and after multiple transmissions of a message.

Number of message transmissions	Percentage usable data bits received				
	Message length (RDS Groups)				
	½	1	2	3	20
2	42	38	29	19	9
3		28	23	16	12
4	23	22	18	13	11
5		18	15	11	10

Table 6
TMC message transmission efficiency using the ALERT B coding strategy and with ±2 kHz RDS deviation after multiple transmissions of a message: minimum and maximum values measured over all route types.

Number of message transmissions	Percentage usable data bits received, min-max				
	Message length (RDS Groups)				
	½	1	2	3	20
2	38-44	33-41	22-32	13-22	3-14
3		27-30	21-25	14-17	6-14
4	22-23	21-23	18-19	12-14	7-13
5		18-18	15-15	10-11	8-11

Table 7
TMC message reception reliability using the ALERT B coding strategy over all route types and after two transmissions of a message. Different RDS deviation conditions are used and also with ARI signals present.

RDS deviation	Percentage messages received				
	Message length (RDS Groups)				
	½	1	2	3	20
± 2 kHz	86	80	71	65	30
± 1.2 kHz	85	77	67	60	26
± 1.2 kHz * +ARI	85	76	64	55	13

* Error files via professional RDS decoder

Table 8
TMC message reception reliability using the ALERT B coding strategy after two transmissions of a message, and for reduced RDS deviation conditions and with ARI signals present: minimum and maximum values measured over all route types.

RDS deviation	Percentage messages received, min-max				
	Message length (RDS Groups)				
	½	1	2	3	20
± 2 kHz	78-91	70-87	54-80	44-76	10-45
± 1.2 kHz	71-95	50-88	41-82	31-78	4-45
± 1.2 kHz * +ARI	80-91	69-85	54-74	45-66	4-24

* Error files via professional RDS decoder.

8.3.4 Comparison of ALERT A and ALERT B

The extent of the comparison which could be made at the Transport layer has been very limited because of the unavailability of multi-Group messages for ALERT A. Fig. 5 shows results for single Group messages only, with standard RDS deviation and for 'all routes'. There is very little difference between them at this layer as might be expected.

8.4 Conclusions of the Transport layer tests

The main points to emerge from the field trials and subsequent test analysis are:

1. No false messages were received with message validation based on receiving a message twice. This is considered to be a powerful mechanism and worth the duplication of data transmission for this application.
2. There is an overwhelming advantage in using shorter messages, based on single RDS Groups or less, as far as both message reception reliability and transmission efficiency are concerned. Longer messages are very unreliably received and generally less efficient.
3. At an RDS deviation level of ±2 kHz, over an average of all types of routes tested, the number of short (single and half RDS-Group) messages reliably received was found to be 80 - 86%, on average, after just two transmissions.
4. Repeating messages generally increases their reception reliability. The 80 - 86% figure for shorter messages sent twice rises to 93 - 94% after four or five transmissions.

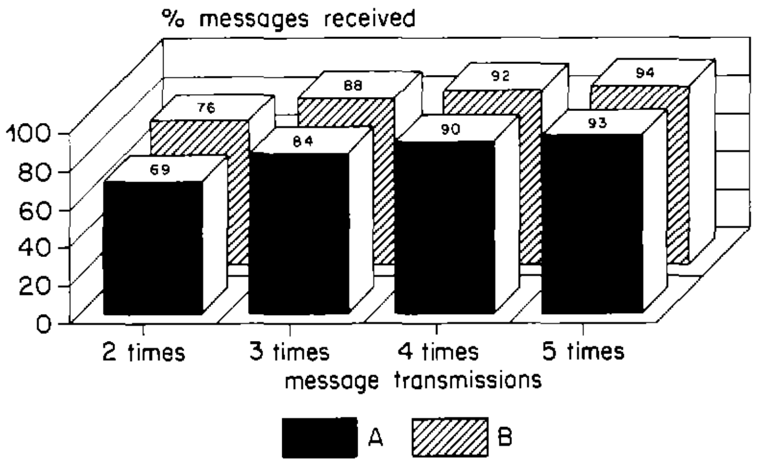


Fig. 5 - A comparison of ALERT A and ALERT B coding strategies: TMC message reception reliability over all route types and with ±2 kHz RDS deviation.

5. No pattern has emerged from the results derived from the different route types tested. This probably reflects: differences in terrain, the shadowing effects of buildings and the various transmission path lengths for the particular routes chosen. It is unlikely that there are other significant underlying reasons, for variations in RDS reception reliability, on the various roads used.
6. Message reception reliability is reduced at lower RDS deviations and when ARI signals are also present. Under these conditions, the reliability of a TMC service would be marginal.
7. There is very little difference between the ALERT A and ALERT B TMC coding strategies at this layer.

9. SESSION LAYER TESTS

9.1 Objective

The message management strategy, adopted by both broadcaster and in the receiver, is a key factor in determining the time delay between when a message is first broadcast and when it is received correctly. The purpose of the Session layer tests was to investigate how the *message delay* is affected by the message management strategy. Two different circumstances were considered:

i) a fixed number of messages;

ii) a fixed rate for introducing new messages.

The first case represents a general steady state situation, where a number of current messages are already being broadcast and where new ones are being introduced relatively infrequently. This situation might apply, for example, when a receiver is newly switched on or enters a new service area. The time required to receive all the current messages correctly is directly relevant to the motorist in this situation.

The second case applies when a broadcaster begins to send out messages, for example, at the beginning of a day.

Other factors were considered but it was not possible to deal with these in this project. These included a study of what proportion of messages could reasonably carry additional information. This implies that a proportion of messages would be carried in several RDS Groups. Also, the proportion of messages which could be encoded in a special shorter form, occupying a half-Group, as proposed in ALERT B is of further interest.

9.2 Input parameters

Large values of the number and rate of messages were used to test the system to its limits. A distinction was made between messages which could be treated as a 'normal' priority and those which could be considered more 'urgent'. These were examined separately.

The input data used for the Session layer tests was a timed sequence of messages, chosen at random from a message list, and included message management descriptors so that the broadcaster and receiver could work out how to handle the message. For example, if the message was an urgent one, the broadcaster would need to insert it more frequently and the receiver might then have a much greater chance of receiving it quickly and reliably. In this case also, the receiver may need to take some executive action to warn the listener of the message, or interrupt his listening.

The input message data list, referred to as a Master Command File (MCF), was generated using a software package 'STEST', which was developed at BBC Research Department, and run on a standard PC-AT compatible machine. The parameters associated with each message in the list are: a serial number, the time at which the message is sent, a set of message management 'flags' (see below), an event description which includes location, location offset, category, any quantifier, and a stop-time to indicate when to stop sending the message. Each message also includes two further times, to indicate when new messages will replace the original by way of updates. When a message is an update of an earlier message, the number of the original message is also given. New messages are created to replace those which reach their stop-time or when an update message is required.

Two distinct types of list can be made, for a specified test period:

i) **Constant number**

A constant number of messages exist at time t = 0 and all messages are treated with equal priority;

ii) **Ramp**

Messages are generated at a uniform rate from time t = 0 and all messages are treated with equal priority.

For transmission purposes, the lists contain the original and any replacement messages, taking the total number of messages slightly beyond that specified at the outset.

The stop-times and update-times, associated with the messages, are generated randomly but weighted by a distribution which peaks between one and two hours, from the time they were generated, and tails off to nothing at fifteen hours.

The flags, which determine the individual message characteristics, are chosen on a random basis. For example, from the percentage of messages required to have quantifiers, the quantifier flag will be raised, on average, for that percentage of the test period. The locations, events and quantifier values are generally chosen on a random basis.

Initial values for the fixed number and fixed rate of messages were chosen with the intention of allowing them to approach or exceed the saturation point of the system. For the normal message test, two values of a fixed number of messages were chosen (500 and 1000) and two values of a message rate (5 and 10 new messages per minute). Both the tests were confined to two hours, although a much longer period would have been preferred in order to model more closely a daily pattern of supplying traffic information to motorists. The choice of test period was a compromise between an ideal and what could be practically encoded and tested for all the impairment files available.

For the urgent message test the corresponding values for a constant number condition were 50 and 100 and for the constant rate condition they were 2 and 5 new messages per minute. This test lasted for just 20 minutes.

For all the tests, a maximum of four Type 8A Groups per second were permitted. There were two reasons for this compromise. Firstly, although broadcasters would generally use lower TMC transmission rates in order to safeguard basic RDS features, they might use higher peak rates for brief periods. Secondly, the higher rates allowed more messages to be processed, and thus more information to be gathered within the very limited time available for these tests.

9.3 Results

The spread in the results over the different route type categories was small, so only the results for an 'all routes' case are given here. All the results presented here were tested with an RDS deviation of ±2 kHz. It was possible to test only ALERT B satisfactorily for the initial tests but a comparison was possible for the tests involving urgent messages.

After each test was completed, the delay, incurred from transmission to correct reception of each message, was logged and the percentage of messages experiencing different delay intervals was tabulated.

9.3.1 Non-urgent messages

9.3.1.1 Fixed number of messages

Table 9 shows the percentage of messages which were transmitted and correctly received over the period of the test. Fixed numbers of messages were available from the start and values of 500 and 1000 were tested. When there are 500 messages, for example, almost half are received within one minute.

Table 9

TMC message reception delay resulting from the transmission of large numbers of messages and using the ALERT B coding strategy for all route types and an RDS deviation of ±2 kHz.

Time from start of test	Percentage messages received for a constant number of messages	
	500	1000
Less than:		
5 seconds	29.6	14.6
10 seconds	41.1	15.8
1 minute	49.7	17.9
5 minutes	60.3	21.2
10 minutes	81.8	27.2
30 minutes	96.0	56.7
1 hour	96.9	76.9
2 hours	96.9	92.7

There is a noticeable, and not surprising, worsening of performance when the number of messages is increased from 500 to 1000. For 500 messages, 96% are received within half an hour whereas, with 1000 messages, less than 57% are received. Although some messages were not received within the two hour test period, it is likely that these would eventually have been received, and not lost completely, had the test period been extended.

In this test, it was judged that the messages had been formed into cycles of about 15 minutes. With the permitted maximum of four TMC Groups per second, there would be approximately 1800 message transmission opportunities per cycle. Taking into account the need for two correct receptions of a message, before acceptance as valid in the receiver, a cycle would be capable of supporting 900 duplicate message-pairs. Numbers of messages beyond this are, therefore, likely to lead to either a longer message cycle or to force messages to be delayed until the next broadcast cycle: both these factors lead to longer message delays and are indicative of a number limit for the system.

On this basis, it is evident that, for 500 messages, more than 80% are received within the first cycle. For a more realistic data transmission rate, of one RDS Group per second, the number of messages supported at this level of reliability will be further reduced. This reduction may not be on a *pro rata* basis, however, because of the cycle lengthening factor which comes into play when the number of messages exceeds 900. Although it is not possible to state precisely what number of messages could be supported, at an acceptable level of reliability, from the tests conducted so far, the tests on urgent messages give a clue. The results for urgent messages, presented in Section 9.3.2, indicate that, if there were only 100 messages and treated with equal but 'urgent' priority, most (sometimes all) could be received within ten minutes at approximately one RDS Group per second. It is estimated, therefore, that between 100 and 200 messages could probably be accommodated at a 'normal' (non-urgent) level of priority, such that 95% of them could be received within ten minutes.

9.3.1.2 Fixed rate of messages

The results for fixed message rates of 5 and 10 new messages per minute are given in Table 10. The delay, tabulated for each message, is that measured from its first transmission. Once transmitted, all messages are treated with equal importance. However, the number of messages increases during the period of the test so that the earlier messages transmitted are likely to be repeated several times. Messages introduced towards the end of the test may only be sent once, and because at least one correctly received repeat is required for validation, these messages may not be received within the test period.

Table 10
TMC message reception delay resulting from the transmission of saturation levels of new message introduction rates using the ALERT B coding strategy for all route types and an RDS deviation of ±2 kHz.

Delay from transmission	Percentage messages received for a steady rate of messages	
	5 per minute	10 per minute
Less than:		
5 seconds	37.8	29.6
10 seconds	46.9	34.4
1 minute	47.3	37.3
5 minutes	47.5	43.7
10 minutes	47.6	51.9
30 minutes	65.5	67.3
1 hour	83.9	84.8
2 hours	94.9	92.1

Even at these artificially high rates of new message insertion, a significant proportion are received within seconds of their first transmission. Around half are received within one message cycle. The remainder may take several cycles to be acquired: the precise number of cycles depends critically upon the message management strategy adopted. As the total number of messages accumulates, new messages have to be accommodated within an ever-lengthening message cycle. Therefore, if normal priority new messages are not received within their first transmitted cycle, it is likely to be several cycles before they are correctly received. In these circumstances, the resulting message reception delay is likely to be unacceptable.

The rates, of new message insertion tested, illustrate the delay penalty encountered if all messages are assigned an equal priority by the broadcaster. In practice, it would be more appropriate to distinguish the more important new messages from those of a lower priority, such as 'background' messages (for example those describing long-term roadworks, etc.). In this case, the receiver response to new messages will be considerably better than this test indicates. It is not possible to draw a conclusion concerning the exact rate insertion that can be tolerated for a new message, especially at more realistic data transmission rates. It is possible to state, however, that if a message is sufficiently urgent, it should be given an initial transmission priority to ensure that correct reception is highly likely within one message cycle.

9.3.2 Urgent messages

The results for a fixed number of 50 and 100 messages, taken over all routes for both ALERT A and ALERT B, are given in Fig. 6. The message delay times are now considerably shorter than for the normal category of message, and reception reliability is increased.

The message response time approximately doubles when the number of urgent messages is increased from 50 to 100, for both ALERT A and ALERT B. ALERT A seems marginally favourable for the first 15 - 30% of messages which are received within about 15 - 20 seconds. After this there is a distinct advantage for ALERT B. For both ALERT A and ALERT B, there were always some messages which took longer to be received, but all messages were received satisfactorily by the end of the test period (allowing for the end-effects of the test). For

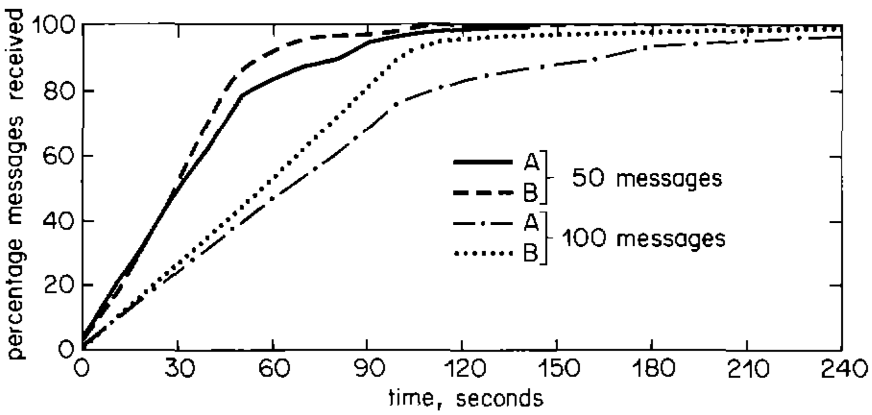


Fig. 6 - TMC receiver response for 'urgent' messages using ALERT A and ALERT B coding strategies for all route types and an RDS deviation of ±2 kHz.

realistic TMC data rates, the responses shown in Fig. 6 could be extended *pro rata* by a factor of four, so that, for example, with fifty urgent messages (and no others) all might be received within eight minutes, although 95% might be received within four minutes.

Tables 11(a) and (b) summarise the results for the ALERT A and ALERT B steady rate tests for the cases of two and five new messages per minute respectively. New urgent messages can be processed very quickly and about 90% are received within a minute. However, more messages appear within a few seconds using ALERT B when compared with ALERT A. At least 80% of messages are received within two seconds for ALERT B whereas it is less than 50% for ALERT A. Taking into account the large numbers of urgent messages used in the tests, and allowing for the presence of other messages of lower importance, the results indicate that, with more realistic levels, the reception of urgent messages is likely to be very efficient.

9.4 Conclusions of the Session layer tests

The following conclusions are drawn from the tests conducted over all route types and using an RDS deviation of ±2 kHz. They are presented in terms of a more realistic data rate of about one TMC Group per second:

1. When messages are treated with equal importance, the number of messages which could be supported, to provide a reasonable probability (say 95%) of correct reception within (say) ten minutes, is likely to be between 100 and 200 using the ALERT B coding strategy.

Table 11
TMC 'urgent' message reception delay resulting from the transmission of saturation levels of new message introduction rates using both ALERT A and ALERT B coding strategies for all route types and an RDS deviation of ±2 kHz.

(a) 2 new messages per minute.

Delay from transmission	Percentage messages received with 2 new messages per minute	
	ALERT A	ALERT B
Less than:		
1 second	0	47.9
2 seconds	33.3	85.4
3 seconds	66.7	86.4
10 seconds	81.7	86.4
60 seconds	91.7	86.4
120 seconds	93.3	96.6
180 seconds	93.3	100.0
Missing	6.7	None

(b) 5 new messages per minute.

Delay from transmission	Percentage messages received with 5 new messages per minute	
	ALERT A	ALERT B
Less than:		
1 second	0	31.0
2 seconds	45.3	80.5
3 seconds	79.3	88.9
10 seconds	80.3	88.9
60 seconds	86.7	88.9
120 seconds	88.7	98.0
180 seconds	88.7	99.3
Missing	9.0	None

2. Prioritising of messages for transmission is important, to ensure that they are received reliably and within an acceptable delay period appropriate to their allocated priority.
3. Urgent messages are treated as such by both proposed coding strategies, and response times are considerably faster than for normal messages.
4. On balance, ALERT B has advantages over ALERT A.

As with the Transport layer tests, much poorer results were obtained with reduced RDS deviation and/or with ARI signals present. Under these conditions, the delay in receiving urgent messages reliably may become unacceptable.

10. OVERALL CONCLUSIONS AND RECOMMENDATIONS

The more general technical conclusions which can be drawn from the results of the Transport and Session layer tests, presented above for the two preliminary RDS-TMC coding strategies, can be summarised:

1. At an RDS deviation level of ±2 kHz and with a single RDS Group per second dedicated to TMC, the reception reliability of RDS-TMC messages is expected to be adequate to support a TMC service within the primary service areas of FM broadcasting stations. This, however, is conditional upon the restrictions of both message length and capacity, and upon messages being allocated an appropriate priority. The latter condition is determined, editorially, by the relative importance of a message.
2. At lower RDS deviations, and particularly where ARI signals are also present, reception reliability is reduced and is expected to be only marginally adequate for a TMC service.
3. TMC messages must be kept short, such that the vast majority of messages can be encoded as single or half-RDS Groups (37 or 18 bits available).
4. The maximum number of concurrent messages, which could be supported at a TMC data transmission rate of one RDS Group per second, is likely to be between 100 and 200. This would provide an acceptable probability (say 95%) of correct reception within (say) ten minutes.
5. A double reception of a message has been assumed for message validation in the receiver. This is considered the preferred manner of error-protection for this application. No false messages have been detected under this condition.

Subsequently, the ALERT C coding strategy for RDS-TMC was developed to include the best features of both ALERT A and ALERT B. Many of the test results which have been presented here are expected to remain valid for ALERT C. Based on the results of these and related tests, ALERT C has already become widely accepted as a way forward for RDS-TMC. Although not formally adopted, ALERT C is suggested by the relevant EBU and ECMT bodies as a basis for future work.

It is recommended that additional technical tests are carried out, to determine the operating margins of the ALERT C coding strategy as part of, or as a precursor to, a larger field trial. In particular, these tests should include investigation of:

a) message cycle length and message repetition frequency, in order to provide a reliable service for messages of different levels of importance within the available RDS data capacity.

b) message management during the introduction of new messages, taking into account their relative importance.

c) the effect on system performance of including a proportion of messages which generally require multiple RDS Groups to encode them.

d) the proportion of messages which can be encoded in half-Groups.

e) the encryption and multichannel operational aspects of the coding strategy for which appropriate hooks are provided within ALERT C.

In summary, the main objective stated in Section 5 of this Report was 'Will TMC work and provide a usable service within the constraints of RDS?'. The conclusions drawn above indicate that the technical performance of RDS-TMC is expected, given the constraints noted above, to be adequate to support a limited service. However, the usefulness and acceptability of such a service was not addressed in these technical tests and would need to be the subject of a separate investigation. There are many other aspects, besides that of the technical level of performance, that will need to be assessed.

A second phase of DRIVE is planned to start in 1992 and the main thrust will be to concentrate on *projects* which have benefited from technological development in the first phase and carry them through to a full further field trial. It is envisaged that TMC is likely to be amongst the chosen projects. The successful completion of such trials would build further confidence in this system and provide substantial support towards standardisation.

TMC is also being discussed in relation to other carriers and it may be possible to establish some commonality of message format, especially at higher levels. These carriers include cellular telephone networks, paging systems and Digital Audio Broadcasting (DAB).

11. ACKNOWLEDGEMENTS

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APPENDIX 1

ISO-OSI Model

The Reference Model of Open Systems Interconnection (OSI)[10,11] is already widely accepted as an appropriate framework for modelling complex communication systems and the basic principles are not described here. Although the ISO-OSI Model was originally defined only for communication systems, in which explicit connections are made (i.e. point-to-point telecommunications), the model has more recently been extended (see Addendum 1 to ISO 7498) to connectionless environments such as broadcasting. Furthermore, broadcasters in the CCIR have decided that all future digital broadcast systems should be defined and analysed in terms of this model. The CCIR is currently studying framework definitions of the layers to assist this process. The original RDS Specification (EBU Doc. Tech. 3244) was based on the model.

The ISO-OSI Model is centred on the customers' requirements (i.e. the end-use of a communication system). These requirements are seen as providing a convenient, reliable and low-cost service whilst making an efficient use of the available resources (RF spectrum, communications equipment, etc.). It is well suited, therefore, to seeking an optimal coding structure for RDS-TMC.

In simple terms, the overall task of the Model is sub-divided into a seven-layer structure, each layer of which can be treated independently of the others. The seven layers are defined in reverse order as:

Layer 7:	Application
Layer 6:	Presentation
Layer 5:	Session
Layer 4:	Transport
Layer 3:	Network
Layer 2:	Data-link
Layer 1:	Physical

A human user interacts with a system only at the highest Application layer. All of the lower layers are of no direct concern to him, but each succeeding layer down the model plays its part in servicing an increasingly more tangible and detailed level of the system. At the lowest Physical layer, a system generally comprises the physical communication media, such as wires, plugs/sockets or radio-frequency bearers, etc. From the lowest layer and upwards, individual *services* are provided to succeeding layers. The *user* of the services of each layer is the next layer upwards. At the Application layer the end-user is the human.

A 'top down' approach to system design means considering the application first. This is what a potential user might most easily be able to define. Increasing technical detail can then be added to service the application, both at the sender and, in a complementary manner, at the receiver. The top-down approach is one of a **need** looking for a **technical solution.**

A 'bottom-up' approach, on the other hand, is one where there is some kind of carrier or bearer to start with and there is a search for something to do with it, i.e. some application to service.

There are carefully defined rules governing the flow of data from one layer to another, and between the data sending part of a layer (*the sending entity*) and the data receiving part (*the receiving entity*). Data is transferred between layers as *data units* according to a set of *primitives*, and are handled within each layer according to a set of *protocols*. For example, at the receiving-end of a system, the data used in the Session layer consists of Transport layer data (Transport data protocol units — TDPUs) whose transfer is controlled by certain primitive rules according to the service supplied by the Transport layer.

The 'top' layer is always taken to be the Application layer 7. In a communication system based on the model, the 'sender end' services the application with lower layer functions. The connection to the 'receiver' is via the 'bottom' layer 1. At the receiver, the layers are built upon to serve the application to the end-user.

In applying the ISO-OSI Model to RDS-TMC, the functions which correspond with each layer are defined as follows:

Layer		TMC function at sender	TMC function at receiver
7 Application		Information gathering, collation and other editorial functions.	The interpretation of messages and the driver reaction.
6 Presentation		Message coding and content: Translation of message data into a TMC vocabulary.	Recovering the messages in, for example, a spoken, printed or displayed form.
5 Session		Message management: Forming message cycles, giving priority to more urgent messages, updating messages, removing old messages.	Message management: Keeping track of current messages, separating more urgent messages, updating messages, removing old messages.
4 Transport		Mapping of the messages into Type 8A RDS Groups, message-level error protection, including message repetition.	
3 Network	*	Provision of a multiplex of 16 RDS Group types, each containing 37 user bits.	
2 Data-link	*	Formatting of the RDS bit-stream into Blocks (of 26 bits) and Groups (4 Blocks), Block and Group level error protection and synchronisation.	
1 Physical	*	Provision of a phase-modulated 57 kHz subcarrier and its conveyance via an RF bearer.	

* Already provided by the RDS Specification.

APPENDIX 2

Description of Test Strategy

There are four stages in the test process: only the first is concerned with measurements on the road — the remaining stages can be carried out in the laboratory. Each stage is described briefly and, as data files are introduced, they are allocated labels assigned from the following list:

i) Error-free 'clean' data;
ii) Reception-impaired data;
iii) Reception-impaired binary errors (ii − i);
iv) TMC message (+ RDS background) input data;
v) 'Reception-impaired' TMC input data for 'transmission' (iii + iv);
vi) TMC receiver message output data.

Field trial

Using existing off-air RDS data transmissions and a mobile receiver connected to a wideband analogue tape recorder, the whole of the FM multiplex signal was recorded. Real error statistics were thus gathered to represent the reception impairments of FM broadcasting as encountered along selected routes. This stage required no prior knowledge of the precise coding strategy to test. At the same time, a 'clean' data file (i) was obtained on a laboratory workstation from an error-free reception of the off-air signals. The vehicle used for the field trial and the operating conditions for the tests are described in Appendix 3.

Data transfer

A block diagram of the laboratory equipment is given in Fig. A2.1. Referring to the top-left, the recorded FM multiplex signals from two FM stations (made during the mobile field trial) were replayed and the RDS data demodulated and decoded. The data was transferred to a workstation (via a PC interface) and held as a reception-impaired data file (ii). In combination with a corresponding 'clean' data file, an 'error' data file (iii) was derived. The error file is a continuous stream of binary data which could be claimed to be a replica of the error conditions experienced during the field trial. Separate error files were generated for each journey assessed.

The derivation of the error files required the 'clean' and 'impaired' data streams to be synchronised and a special strategy was developed for this purpose. Synchronisation was achieved with the help of the Clock-Time and date (CT) feature of RDS, contained in Type 4A Groups, and which is already broadcast throughout the UK. Type 4A Groups are transmitted once a minute immediately before a minute edge. Thus the two data streams were searched for a matching Type 4A Group in order to establish a synchronisation point.

However, the process is complicated if the impaired data stream suffers from *bit-slips*, which can occur in particularly poor reception conditions. Bit-slips cause the 'impaired' data stream to be effectively lengthened or shortened by one or more bits. If ignored, this would destroy synchronisation and so the 'impaired' data stream was decoded over several Groups at a time. The presence of bit-slips was checked over this interval and, if recognised, the data stream was corrected before generating the error files, using an exclusive-OR function on the two data streams.

The associated measured field strengths were fed into the computer via ADCs. These field strength recordings are expected to provide supporting evidence for subsequent analysis, with a possibility of extracting multipath information.

TMC input data

A list of test messages was supplied in an encoded TMC data form and, together with background RDS data (bottom-left), was fed into the workstation and held as an input data file (iv). The error file (iii), produced earlier and reflecting the reception conditions applicable during the field trial, was used as an interfering signal. This was added to the RDS-TMC test message data file, to produce a data file containing impaired TMC messages (v).

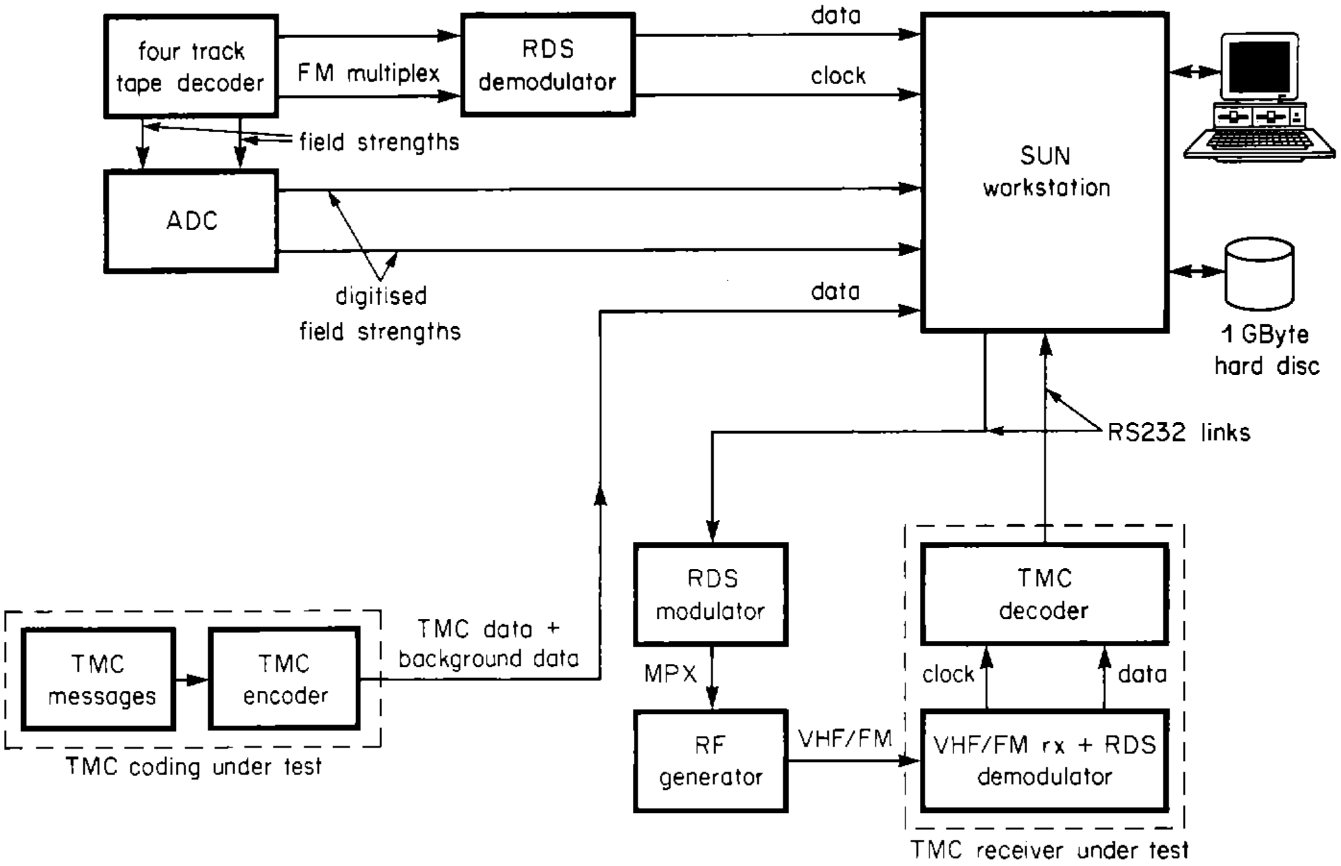

Fig. A2.1 - Block diagram of the laboratory test procedure.

Testing and analysis

The impaired TMC test messages, simulating the original test conditions, were 'broadcast' in real time to a receiver under test through a simulated transmission chain (bottom-right). The impaired test data was connected to a modified RDS encoder*, which behaved as a FIFO buffer and which was kept sufficiently full to allow a steady stream of data at the standard RDS data rate to be generated. The FIFO was of 1 kilobyte capacity and needed to be half-filled to initiate data transmission. The data is supplied from the workstation, via an RS232 standard serial link, at a rate of about 148 bytes every second. This ensured that the FIFO is maintained at an approximately constant level. No handshaking was required for this process because the workstation could provide data at a rate which ensured that the FIFO would neither empty nor overflow during each twenty-minute test period.

The RDS data was fed at the standard rate of 1187.5 bit/sec into an FM signal generator and modulated onto an RF carrier to produce a Band II signal. This laboratory set-up now simulates a receiver located in the vehicle used for the field trial. The signal was supplied to a receiver under test and its decoded TMC messages fed back to the workstation and held as a retrieved message file (vi). The decoded messages were checked against the original list, using the workstation to identify any irregularities which may have appeared.

The purpose of the tests was to compare file 'vi', containing TMC messages recovered from the receiver under test, with the original list of TMC messages from which file 'iv' is derived. The receiving software in the workstation operates on data appearing at a second serial port, which is linked to an output from the receiver under test. Each byte received is placed into a file, converted to hexadecimal format and compared, text character by text character, with the original TMC message file. The essential objective is to keep the workstation informed of the contents of the TMC receiver database.

An initial test was made to confirm the validity of the method by comparing the results obtained by direct measurement in the vehicle and by the simulation approach. This check gave precise agreement between the two and gave a good deal of confidence in the method.

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* Kim Popat of BBC Design & Equipment Department produced the software modification for the RDS encoder.

APPENDIX 3

Description of Field Data Gathering Exercise

Test vehicle

The vehicle used in the field trials was a modified Renault Espace, which is shown together with the installed equipment in Fig. A3.1(a). An equipment block diagram is given in Fig. A3.1(b).

A vertical Band II quarter-wave monopole was fastened to a roof-mounted aluminium ground plane to overcome the limitations of the glass fibre construction of the original vehicle roof. This was an attempt to produce a radiation pattern as near omnidirectional as possible. The measured radiation patterns are presented in Figs. A3.2(a) to (c) for operating frequencies across Band II at 88 MHz, 98 MHz and 108 MHz. Each shows the effect of three different polarisations, namely vertical, positive slant and negative slant*. These are expected to be the most relevant in this situation. The deviation from omnidirectional is no more than ±2¼ dB for vertical polarisation but rises to a maximum of ±7½ dB with slant polarisation at some frequencies. This is considered to be an acceptable level of asymmetry and probably better than is achieved with the factory-fitted units on most vehicles.

The antenna signal was split to feed two commercial RDS receivers and two professional field strength measuring receivers. The former were used to provide the demodulated FM multiplex for recording, and the latter were used to provide a field strength reference. The signal level applied to the commercial receivers was representative of a typical car.

Two channels (1 and 2) were processed simultaneously because there was a future possibility of analysing multi-channel TMC operation and there were four recording channels available on the wideband instrumentation recorder used. The composite multiplex signals for the two channels, each comprising the stereo programme and modulated RDS subcarrier, were recorded in real-time, together with analogue field strength outputs from the measuring receivers. The four tracks were allocated as follows:

Track 1: Received multiplex signal of channel 1;

Track 3: Measured field strength of channel 1;

Track 5: Measured field strength of channel 2;

Track 7: Received multiplex signal of channel 2.

There were several other items of test equipment to assist the recording process. A local RF generator (see Fig. A3.1(b) top-left) was used to provide a calibrated reference to set the recording levels of the field strength outputs of the measuring receivers. An oscilloscope allowed monitoring of the field strength channel outputs of the tape recorder. The composite multiplex signal was fed to a stereo decoder, equipped with headphones, and an RDS decoder so that both the stereo programme and the RDS reception performance could be monitored in order to identify any unusual or equipment-based peculiarities.

Mains power was supplied from a rear-mounted petrol-driven 240 V, 50 Hz generator. A great deal of care was taken in order to minimise Radio Frequency Interference (RFI) on the recordings.

Routes

A sample of test routes, within the BBC Wrotham service area in SE England, was identified, to address three different sets of road conditions. The chosen routes were:

a) Motorway at an average speed of about 110 km/hr;

b) Urban at an average speed of less than about 50 km/hr;

c) Mixed country and suburban route at an average speed of about 80 km/hr.

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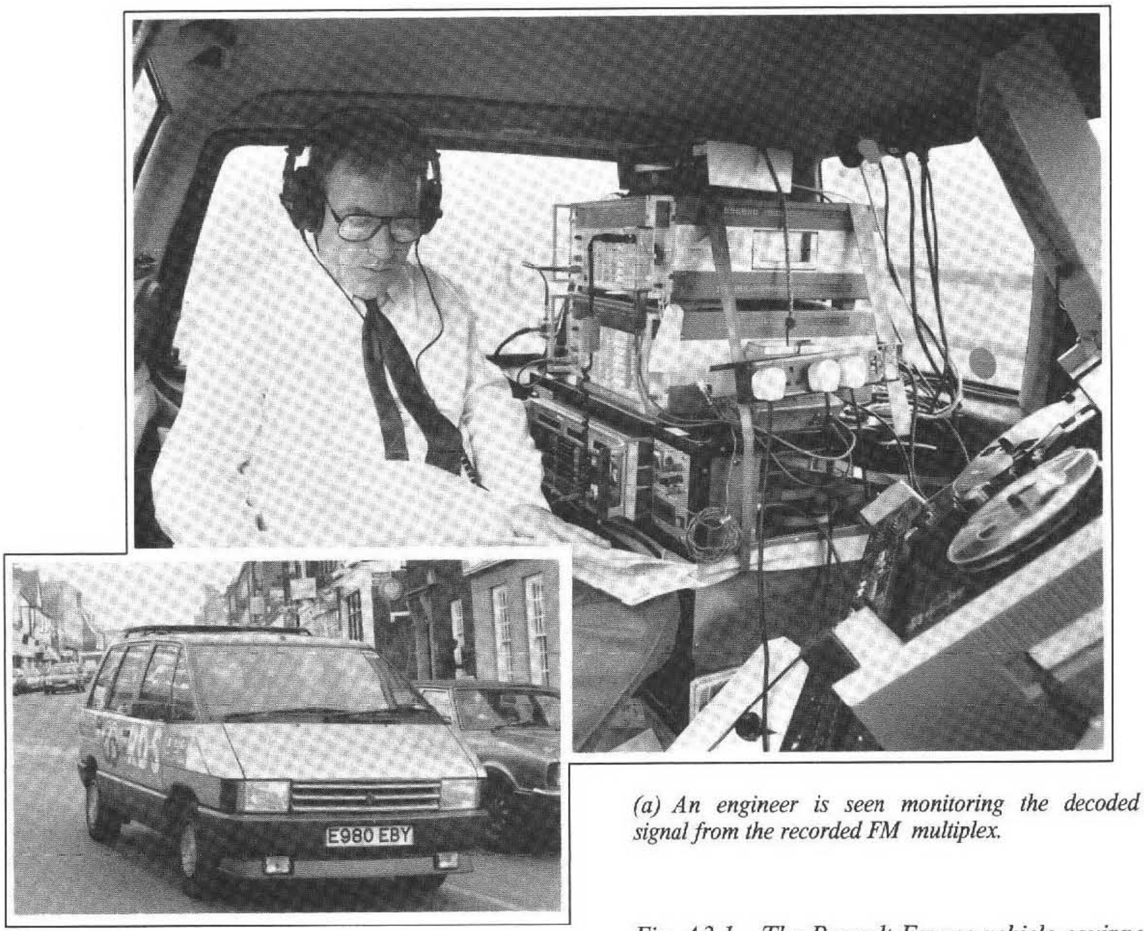
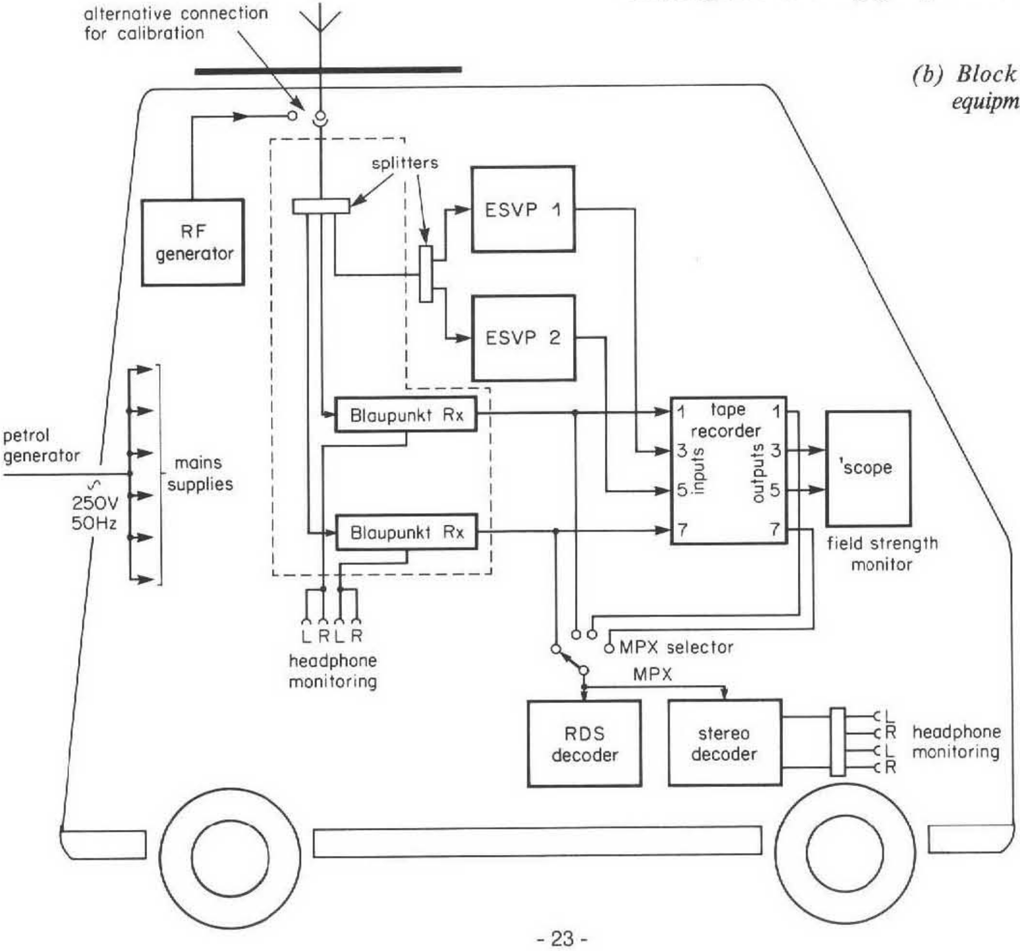
* BBC FM Radio broadcasts use mixed polarisation in order to improve reception in vehicles which are equipped with vertical whip aerials.

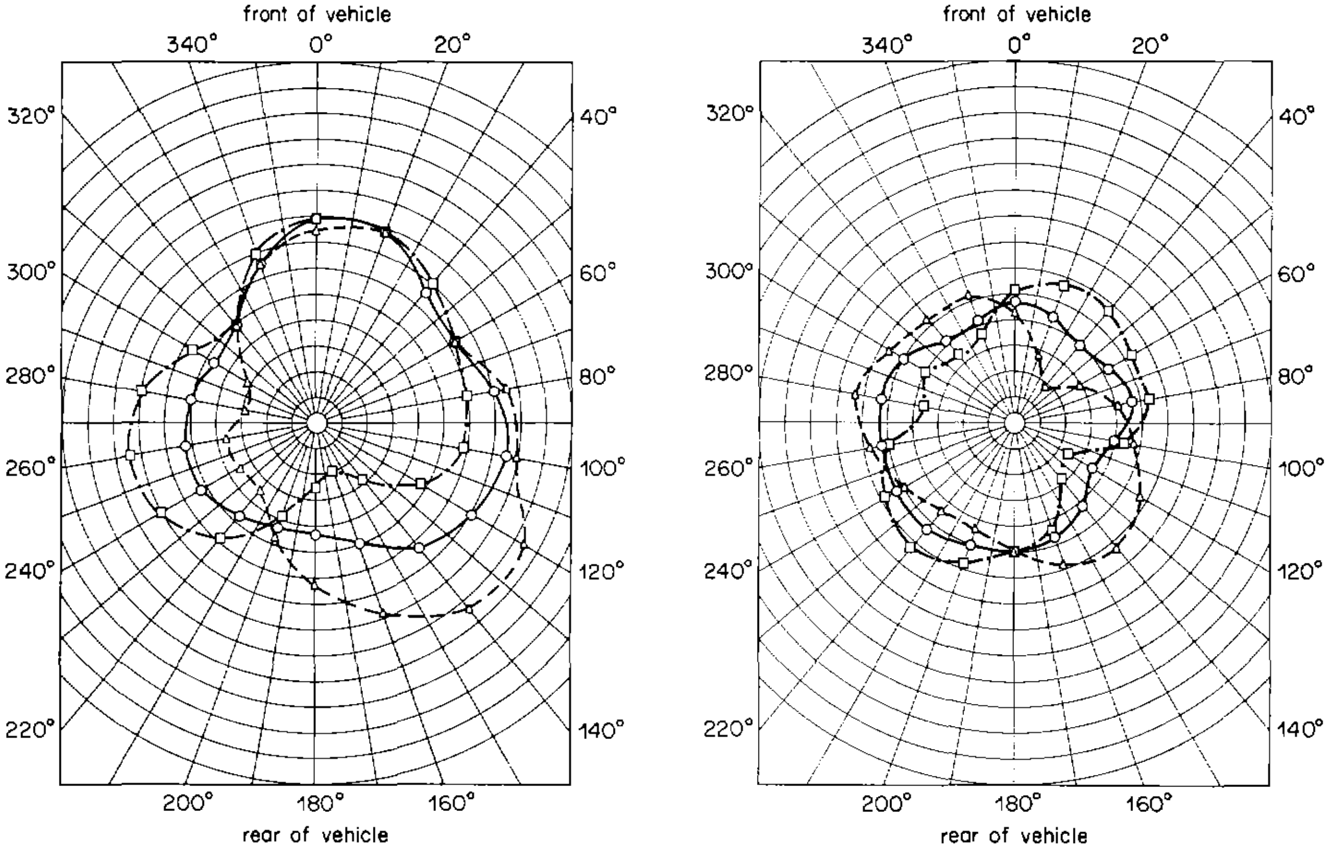


(a) An engineer is seen monitoring the decoded audio signal from the recorded FM multiplex.

Fig. A3.1 - The Renault Espace vehicle equipped with receiving and recording gear for the BBC field trials.

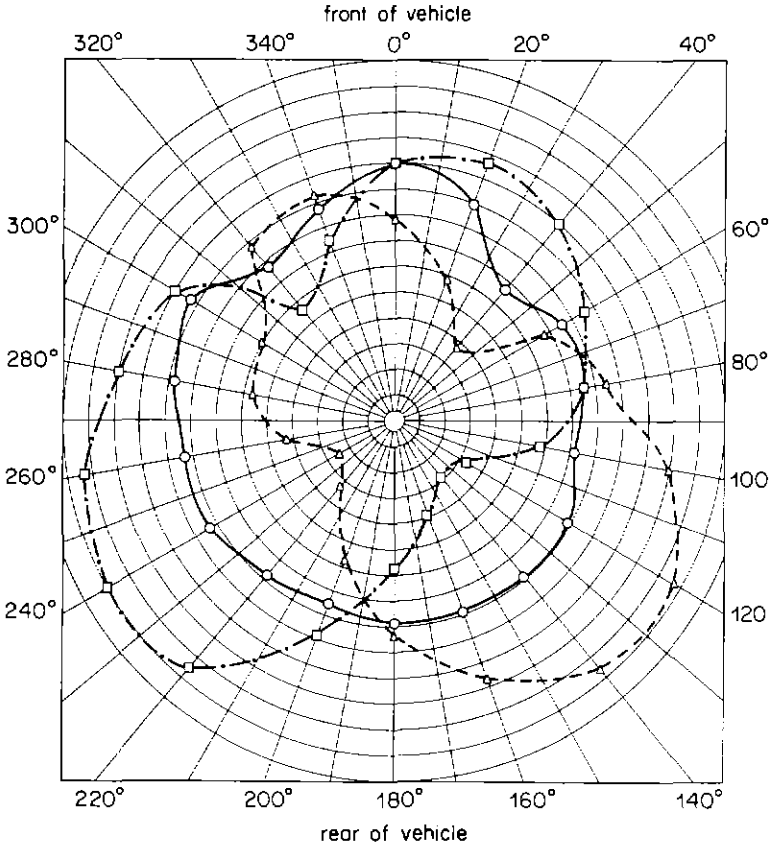
(b) Block diagram of the equipment in the vehicle.





(a) 88 MHz

(c) 108 MHz



(b) 98 MHz

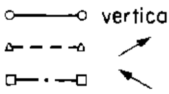


Fig. A3.2 - Measured horizontal radiation patterns for a quarter-wave whip antenna mounted on the BBC test vehicle.

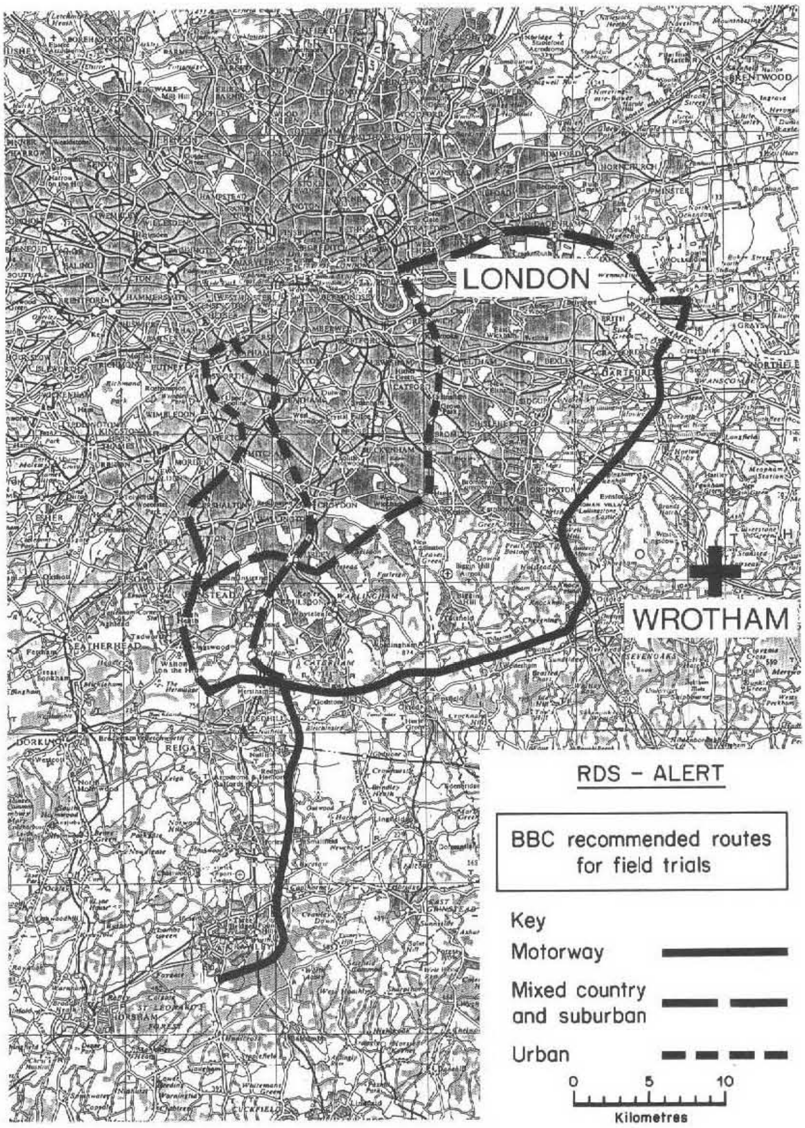

LONDON
WROTHAM
RDS - ALERT
BBC recommended routes for field trials
Key
Motorway
Mixed country and suburban
Urban
0
5
10
Kilometres

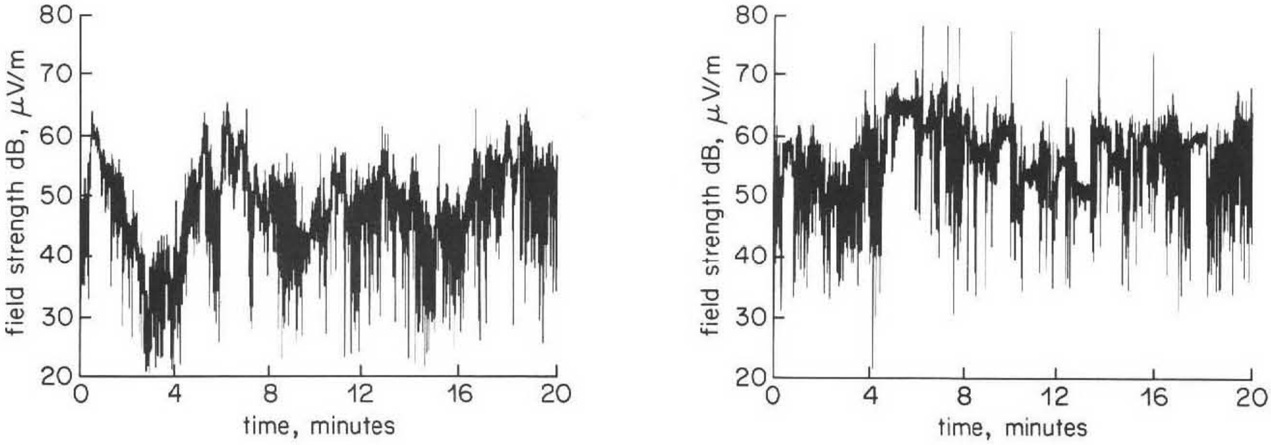
Fig. A3.3 - The routes followed in SE England during the BBC field trials.

The choice of the routes, indicated in Fig. A3.3, was based on a wide experience of the propagation characteristics of FM broadcasting in this area. Over many years, measurements have been made to define service areas and it has, therefore, been possible to identify those areas which are most prone to multipath distortions because of intervening hills or high-rise buildings. They are expected to provide demanding test conditions which thoroughly explore any weaknesses in the proposed coding strategies.

For each route used, a representation of the field strengths encountered *en route* via the vehicle antenna, is given in Fig. A3.4. The results are derived from analogue recordings made during the field trial and are converted to digital values by an ADC interfaced to the workstation. The abscissa and ordinate in each case cover a range of twenty minutes and 60 dB respectively. The maximum field strength value on these figures is 70 dB (μV/m) and the minimum is 10 dB (μV/m).

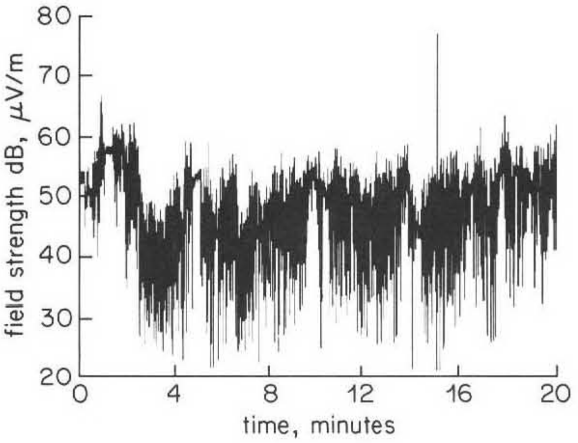
In the first example, shown in Fig. A3.4(a), which is taken from a motorway route, the field strength values occupy approximately the middle of the range, but the characteristic high-amplitude, short bursts of signal variation with distance (time), are evident. There is a pronounced dip near the start which can be identified as the area around the junction of the M23 and M25 motorways and which lies in a shadow from the transmitter and which is also subject to multipath propagation.

The field strength values recorded on the urban route — see Fig. A3.4(b) — are reasonably high but there are many short, sharp disturbances both to very high and low values. In the mixed route case — see Fig. A3.4(c) — the result is a mixture of the two previous cases with an average low to middle level and short excursions to both low and high levels.



(a) Motorway route.

(b) Urban route.



(c) Mixed route.

Fig. A3.4 - Typical field strength recorders, derived from a quarter-wave whip antenna, during field trials.

RDS criteria

The RDS modulation conditions used in the field trials covered a range of options implemented in the different countries of Europe. They are:

a) ±2 kHz RDS sub-carrier deviation (standard in the UK, except for BBC Radio 3);

b) ±1.2 kHz RDS sub-carrier deviation (standard in some countries and used for BBC Radio 3);

c) ±1.2 kHz RDS sub-carrier deviation **and** the inclusion of ARI signals at the standard levels (as used in Germany and some other central European countries).

The first condition presented no problem to implement. The other conditions, however, required special attention and close control, so as not to disturb the public service. Reducing the RDS deviation was relatively straightforward, but the provision of ARI required additional equipment to be installed at Wrotham for the tests; this was switched in only during the test periods.

Clean data

During each data-gathering exercise, a parallel operation was conducted in the laboratory. The feed from a fixed antenna, capable of supplying a clean signal from the transmitter, was split in order to supply a high-quality RF signal to: a pair of VHF-FM Band II professional receivers, a wideband spectrum analyser, a third Band II receiver, and a pen-plotter. The demodulated composite multiplex signals were fed into a pair of RDS decoders; the RDS serial data, together with their associated clocks, were connected to a parallel interface attached to a dedicated PC, prior to feeding on to a workstation.

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